Environmental forecasting for Sustainable Development

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ESRC Research Methods Festival
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3rd July 2008

Why civilisations fail….

- Why civilisations fail (Diamond, 2005)
  - Hostile neighbours
  - Loss of trade partners
  - Climate change
  - Environmental damage
  - Response to environmental problems
- In globalised information world, collapse is no longer expected, but env factors can seriously degrade our Q of L so demand effective long range planning

Content

- **Approaches used in applied environmental forecasting (with examples from own work)**
- **Problems of each approach**
- **Implications for forecasting for SD**

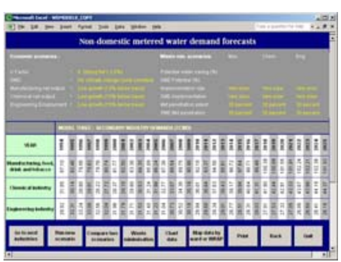
A Physical Model

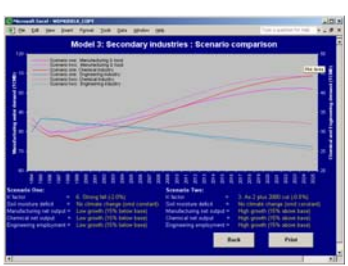
- Oil drilling impact on marine zooplankton
  - Environment replicated (light, temp, salinity, O_2, food)
  - Age standardised population
  - Produced water introduced to populations in equilibrium
  - Impacts traced over multiple-generations
  - Reproductive impacts at orders of magnitude below NOEL from acute tests

Some Problems…

- Replicated environment assumes average conditions
- Small scale assumes exposure (spatial / temporal distribution of PW & zooplankton uniform)
- Other impacts ignored (muds)
- = can’t predict oil rig impact. Did reveal greater ecosystem sensitivity to oil rig operations, guiding future operations

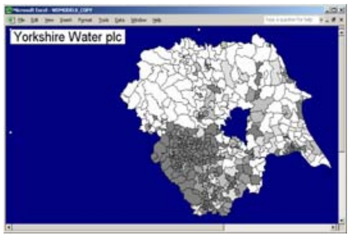
A Statistical Model





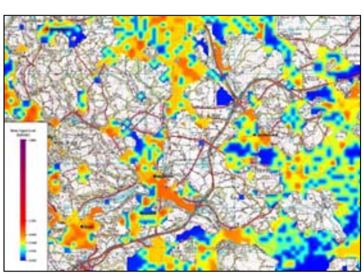
- ND water demand to 2030
  - To address extrapolation problem
  - SIC coded model driven by economy, water service prices, climate and technology diffusion
  - Simple approach but powerful due to diligent reconstruction of past trends and strict adherence to statistical assumptions
  - Proven performance outside generative area over 5 yrs
  - Used by water industry for planning and AMP returns

Some Problems…

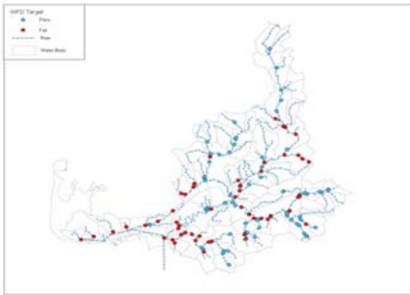


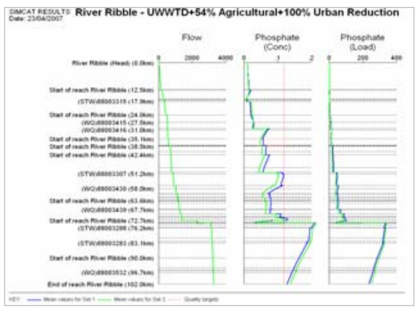
- Downscaling (sub-region, sub-year)
- Events outside generative data (e.g. 2 extreme climate years)
- High uncertainty over technology diffusion, economic futures and Ofwat price controls
- Dynamic interaction – e.g. Ford car plant closure at Dagenham
- = confident of short term (5yr) predictions for region, but not 30 yr and sub-region forecasts

A Probabilistic Model



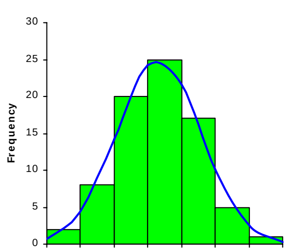
- Urban NPS load model
  - Urban NPS key constraint on meeting WFD RWQ objectives
  - Basin scale / small area model built to aid SUDS planning
  - Statistical runoff model with probabilistic export coefficients for 18 key pollutants
  - Good match of modelled loads to observed for pilot area.
  - Applications include ‘hot spot’ mapping & investigation of urban development / intensification





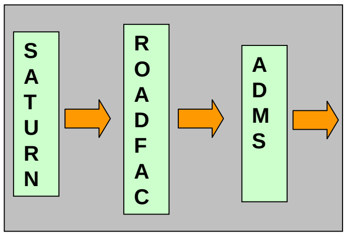
- Integrated application
  - DEFRA ‘source apportionment’ study to support CEA of measures
  - Urban NPS model + Agriculture diffuse model + consented point discharges + observed STW inputs
  - Basin scale small area forecasts by source input to 1100 river reaches in Ribble catchment (Mersey basin)
  - Inputs to SIMCAT mass-balance model to predict water quality throughout the network
  - Reveals step changes in N & P emissions needed to attain WFD targets

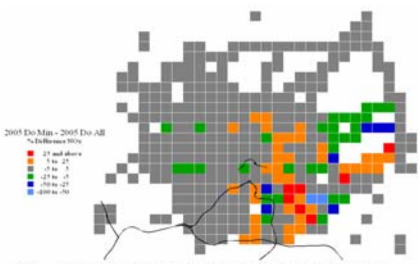
Some Problems



- Poor quality of some geo-data (urban land use, stock density, past N & P application)
- Data averaging (e.g. pollutant emission coefficients by land use)
- Crude assumptions about pollutant transport routes and decay rates from catchment to (and in) river
- External forces neglected (climate change impact on rainfall timing)
- = low confidence in WQ prediction for 2015 by river reach. Does reveal extent of problem, sources / areas to target, and so guiding policy development

A Deterministic Model

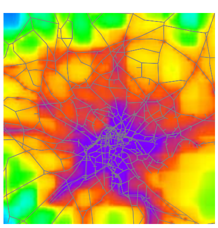




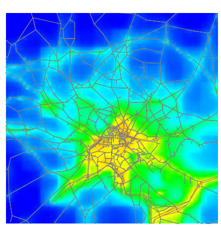
NO_x Emission Response to Network Development

- Linked traffic, emission & dispersion models
  - Detailed representation of traffic route, flow and speed, fleet, emissions (inc PS), air chemistry and dispersion (CFD model)
  - Outputs AQ for 6 pollutants for each of 3600 points for each hour in a year (NAQS compliance)
- Tests
  - Road building, Road pricing (cordons, distance charges), CFVs, combinations (to 2015)

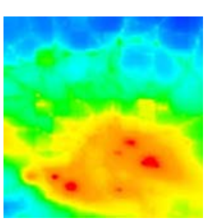
Some Problems



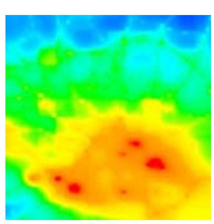
NO_x 1993



NO_x 2015



PM_{10} 1993



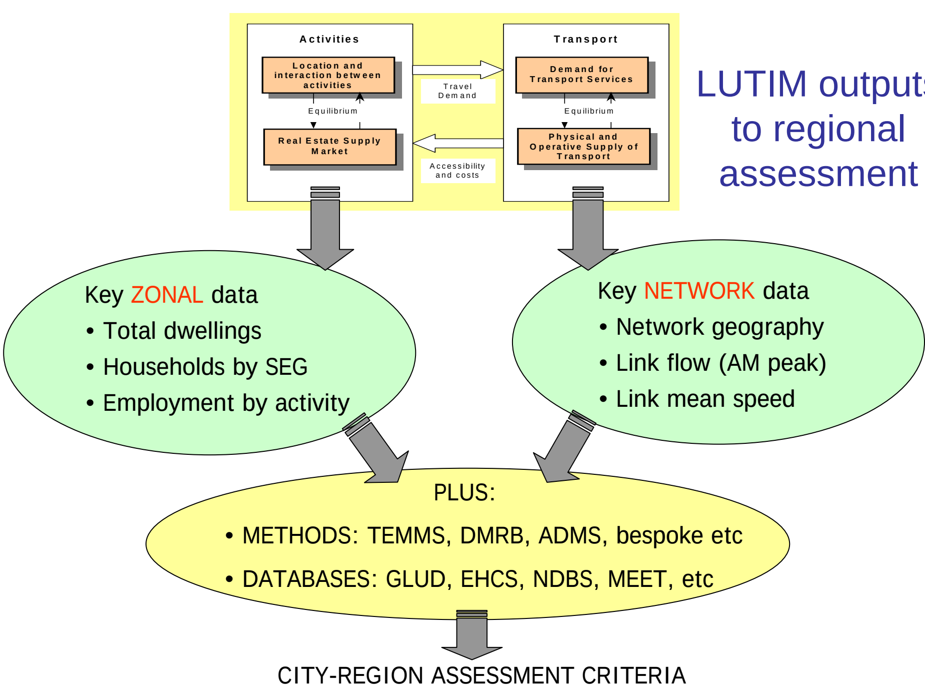
PM_{10} 2015

- Data assumptions (boundary import fleet representation) & averaging (met data, surface roughness)
- Process representation (cold start emission, acceleration / braking, hills)
- Scaling (coarse grid for health work)
- External forces (e.g. PT investment)
- Error propagation through linked models and little observed data to calibrate and validate model to.
- = low confidence in point predictions, but gives advance warning of PM_{10} issue, and reveals distance RUC is most 'sustainable' option tested

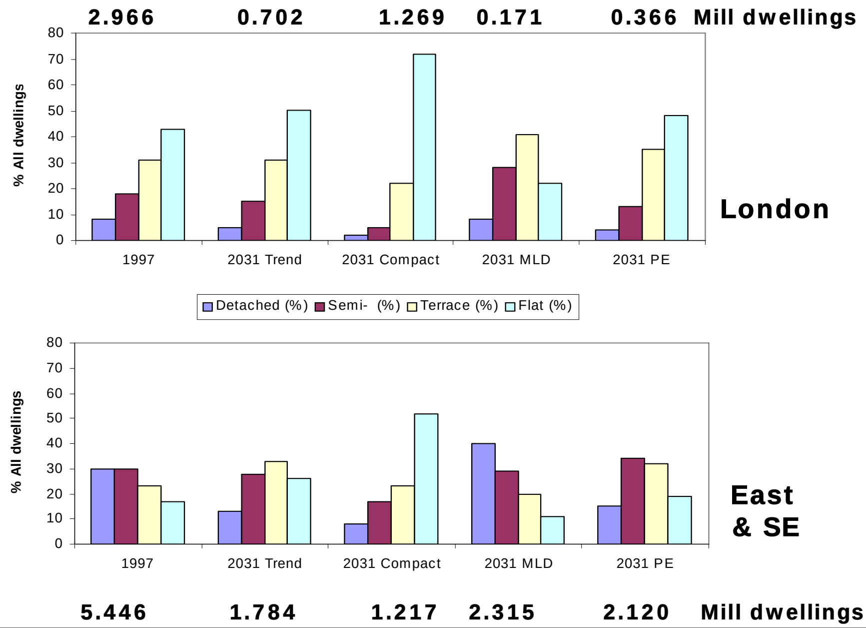
A ‘Consolidated’ Model

- SOLUTIONS – city-region Sustainability modelling
  - ‘Homes for the Future’ : 3 million new homes in England by 2020
  - Debate on the most sustainable forms of spatial development
  - EPSRC SUE consortium project investigating sustainability of Trend and 3 form extremes to 2031

LUTIM outputs to regional assessment

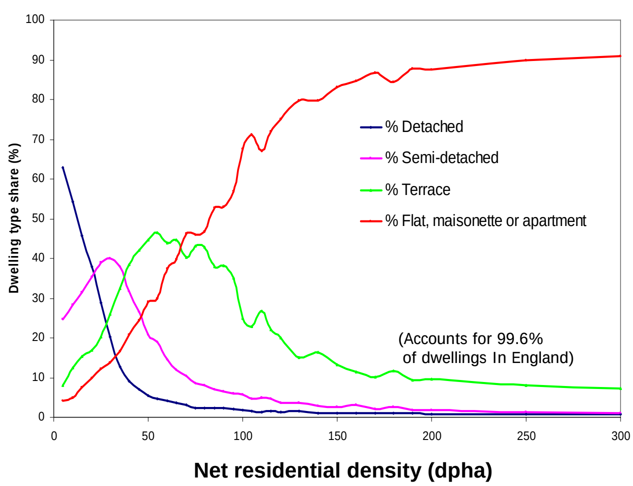


Forecast house type by region and option

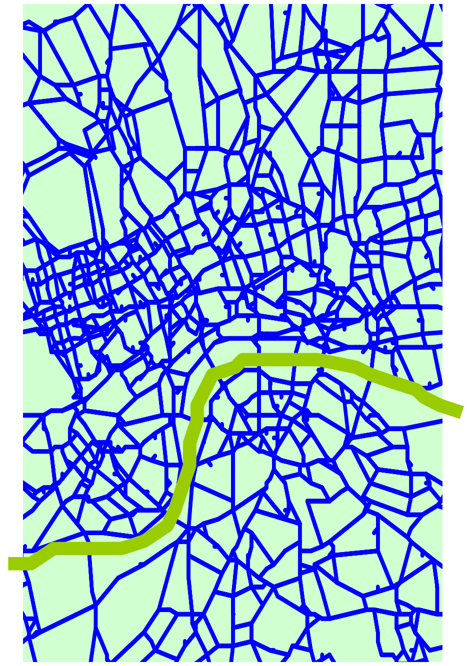


Dwelling share

(% of all dwellings)



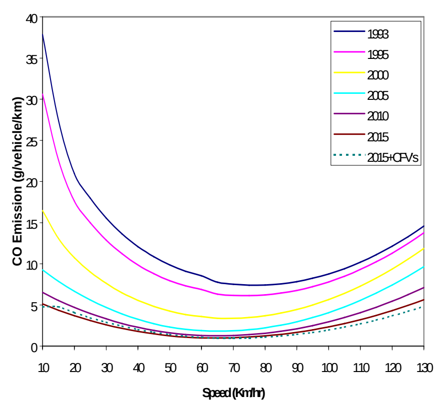
Characterising dwelling types supports onward assessment (e.g. demand for construction materials, energy use in home, floorspace per capita)



LASER network – central London

TEMMS model

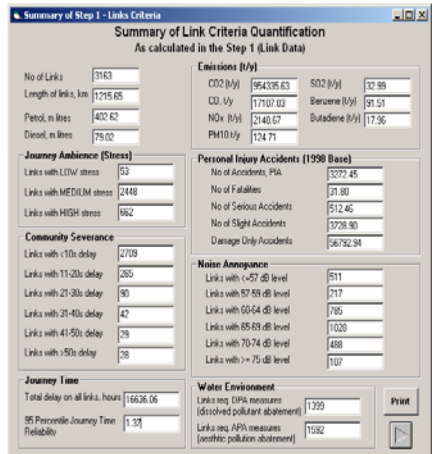
- VB model featuring :
  - 72 vehicle classes (type, size, fuel and engine type, control tech)
  - Speed dependent emission factors recognise UK fleet distribution
  - Cold start correction
  - LASER AM peak flow to 24hr flow profile by road type
- Outputs (mass/link/hr)
  - NO_x, PM_{10} , CO, VOC
  - Petrol, diesel
  - CO_2



Namdeo and Mitchell (2002)
J. Env Modelling Software

SMARTNET model

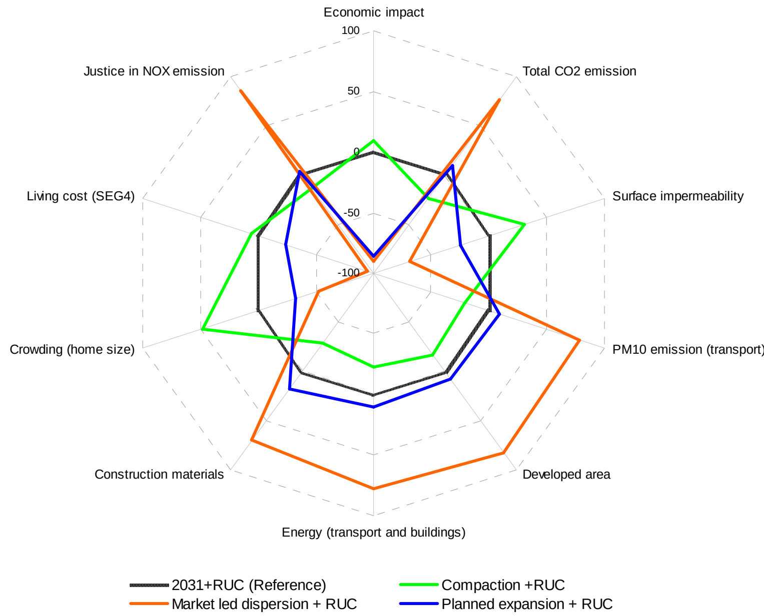
- Extends TEMMS capability
  - DMRB / WebTAG methods (use link type, speed & flow)
- Additional outputs
  - Traffic accidents
  - Noise emission
  - Road runoff
  - Route severance
  - Journey ambience
  - Journey delay



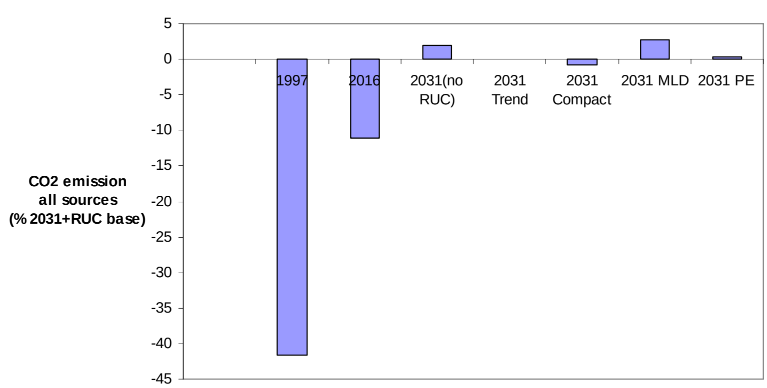
Mitchell and Namdeo (2008)

Vs 2031 TREND	Economy	Resources	Environment	Social
CC	£56 M Cost	Less energy, land & materials than trend	Small reduction in CO_2 and toxic emissions. Highest surface sealing with potential flood / biodiversity impacts	More crowded with higher living cost for low income hholds Fewest RT accidents Social mixing and env equity v. similar to trend
MLD	£574 M cost saving	More use of energy, land & materials than trend	Greatest increase in CO_2 and toxic emissions Dispersed development means least sealing and potential flood and bio-diversity benefits v trend	Least crowded with lowest living cost for low income hholds Most RT accidents Social mixing and env equity v. similar to trend
PE	£543 M cost saving	More use of energy, land & materials, but much closer to trend than MLD	Modest increase in CO_2 and toxic emissions, but very close to trend Less sealing than trend, but likely localised impacts requiring remediation by design	Less crowded with lower living cost for low income hholds RT accidents as trend Social mixing and env equity v. similar to trend

Comparison of options (headline indicators)

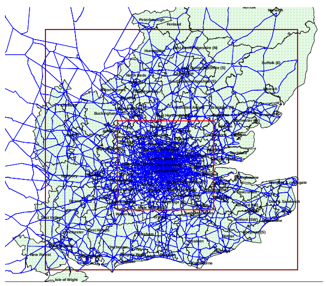


Urban form options in context of long run trend



- In context of long run trend spatial design options have small impact in sustainability terms
- The more sustainable spatial designs are likely to be those which are best able to support technology and infrastructure based solutions

Some Problems



- All of the problems observed in the constituent models (as above)
- No feedbacks to LUTI model (esp. environment quality on location)
- External forces (immigration, fuel price shock)
- Ordering complexity
- Size / complexity = slow, costly, inflexible, not transparent

Problems Summary

- Characterisation of initial conditions
- Errors in characterising processes
  - Averaging of parameters
  - Scaling (up and down)
  - Eliciting variable relationships (esp. if non-linear)
- Omission of important processes
- Treatment of external forces
- Ordering complexity

Environmental forecasting….

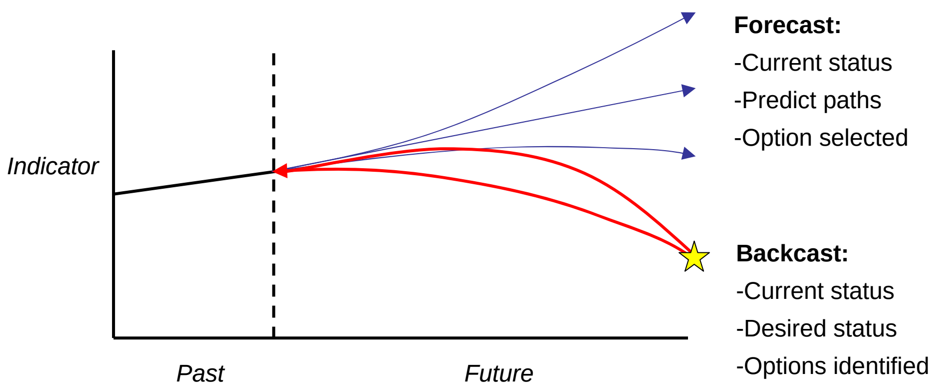
- All types of forecasting approach have applications in the environmental domain
- Environmental models suffer from a range of problems (which are also observed in other domains)
- Models used to make ‘point predictions’ of environmental parameters are usually wrong…...but are often sufficient to inform ‘problem management’

Sustainability forecasting problems

- ‘Consolidated’ sustainability models don’t serve problem management well as :
  - Systems are large and ‘horribly messy’ (RCEP 2007), compounding all the problems simpler models experience
  - Time horizons must be distant, compounding error propagation, and constraining ability to validate models against observations
  - The urgency of SD problems is not well served by unwieldy models
  - Trade-offs are core to SD, but SD models lack transparency
  - SD models are limited in interventions that can be tested – thus innovative solutions that cannot be modelled may be ignored

Think backwards

- Models are poor at predicting 'sustainable futures'…..
  but are important when used with normative scenarios to identify sustainable paths to inform action planning…



Modelling features?

1. Support Adaptive Management via frequent assessment of current vs sustainable path, to review extent of re-orientation needed

2. Strategic scale systems represented using models that are faster (simpler) than current consolidated models

3. Models to include all key subsystems (economic, social, env) and be place specific (problems of LTG *forecasts*)

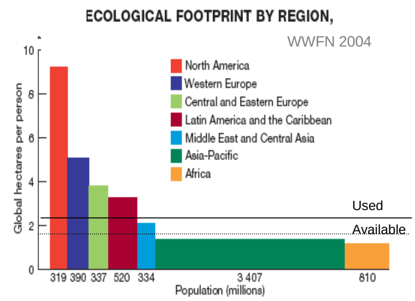
4. 'Tiering' of backcast and conventional models could offer complementarity of approaches (aka SEA – EIA)

5. Normative scenarios require expression of future goals.

   – Many nations already have SD indicators (national to local) with goals set as targets, rate changes, or required direction

   – Example environmental targets at global level include CO_2 emission and ecological-footprint

   – Ecological & carbon footprint goals reveal stark inequalities between nations, and extent of one planet living challenge



Global biocapacity per person = 1.8 ha

Global eco-footprint per person = 2.2 ha

For global population to live as we do in W. Europe = another planet needed

SD forecasting

- Some challenges
  - ‘Technical’ : issues above, multi-scalar nature etc
  - Multi-disciplinary (more interesting?)
  - Fewer sponsors of integrated systems model? (but many customers)
- Social scientists are needed!!….
  - Driving forces data input (demographics etc)
  - Understanding behavioural responses
  - Method experience (comfortable with ‘fuzzy’ methods; no ‘physics envy’)
  - Visioning goals / eliciting and understanding preferences
  - Application of outputs in decision making process (governance)
  - And…???

Thank you

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